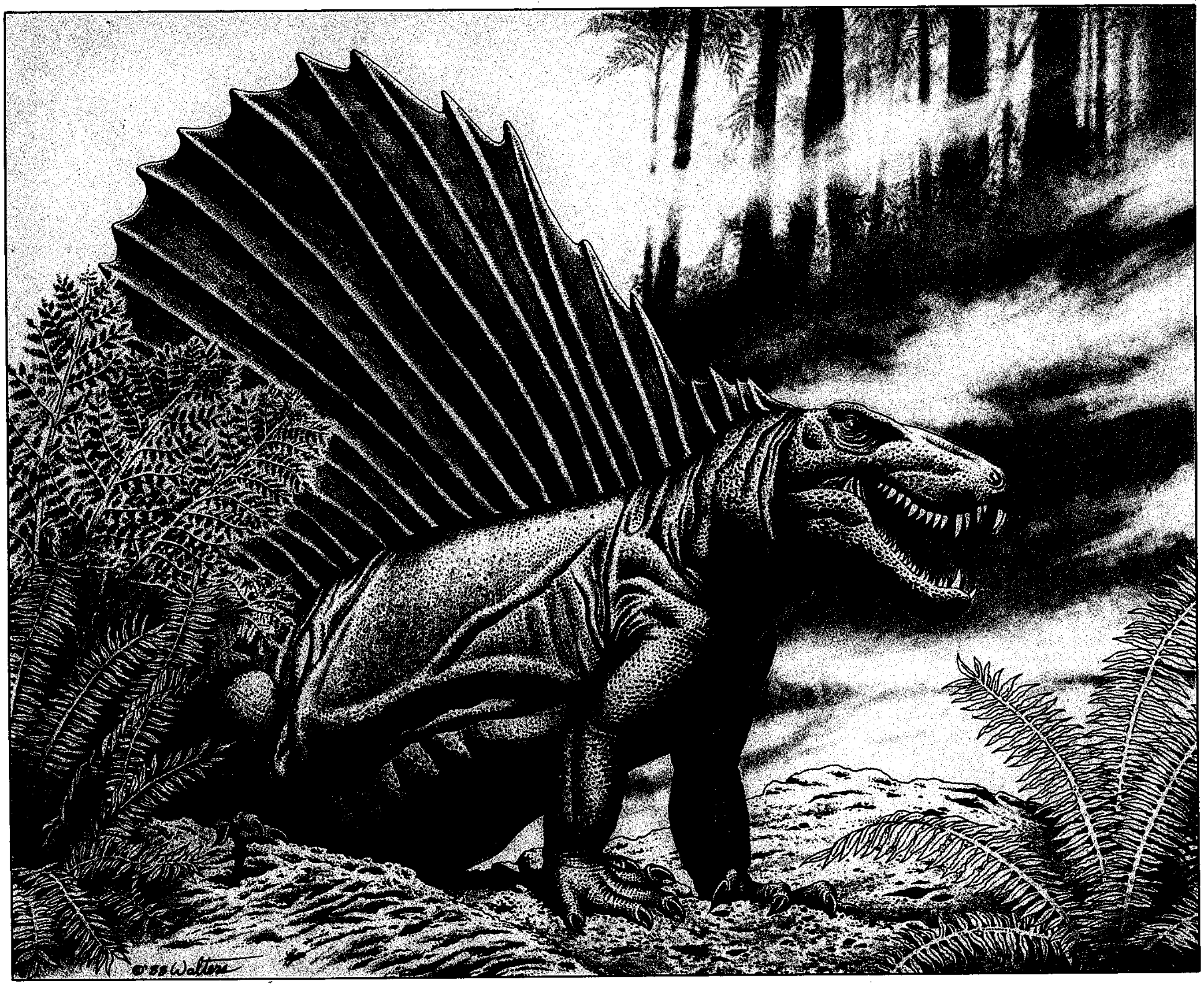
THE MOSASAUR



THE JOURNAL OF THE DELAWARE VALLEY PALEONTOLOGICAL SOCIETY

VOLUME IV OCTOBER, 1989

The Mosasaur

The Journal of the Delaware Valley Paleontological Society

Editor

William B. Gallagher

Associate Editors

Donald Baird
Michael J. Balsai
Earle E. Spamer
Alexander S. Zwil

Stephen J. G. Farrington	*Business Manager*
Robert F. Walters	*Cover Artist*

Computer Publishing Consultant

Eugene A. Lugo
Soft-Tech
Yonkers, NY

The Mosasaur is published on an occasional basis by the Delaware Valley Paleontological Society in Philadelphia, Pennsylvania.
 Copyright © 1989 Delaware Valley Paleontological Society, Inc. ISSN 0736-3907.

Permission to photocopy for internal or personal use or the internal or personal use of specific clients is granted by the Delaware Valley Paleontological Society to libraries and other users registered with the Copyright Clearance Center (CCC), provided that the base fee of $1.00 per copy of the article plus .05 per page is paid directly to the CCC, 21 Congress St., Salem, MA 01970. 0736-3907/89 $1.00 + .05.

Additional copies of *The Mosasaur* may be purchased for $15.00. Checks, bank drafts, or international money orders will be accepted only if payable in U.S. Dollars. Payment is to be made to the order of the Delaware Valley Paleontological Society, or DVPS. **ORDERS** should be sent to "The Mosasaur", c/o Stephen Farrington, Business Manager, P.O. Box 42078, Philadelphia, PA 19101-2078. **EDITORIAL CORRESPONDENCE** should be sent to William B. Gallagher, Editor, "The Mosasaur", Bureau of Natural History, New Jersey State Museum, 205 W. State St., CN-530, Trenton, NJ 08625.

The Mosasaur

The Journal of the Delaware Valley Paleontological Society

Volume IV October 1989

Field guide to the vertebrate paleontology of Late Triassic age rocks in the southwestern Newark Basin (Newark Supergroup, New Jersey and Pennsylvania) 1
Paul E. Olsen and John J. Flynn

Upper Triassic *Dinophyton* zone plant fossils from the Stockton Formation in southeastern Pennsylvania 45
Brian J. Axsmith and Peter A. Kroehler

Notes on six real and supposed type fossils from the Newark Supergroup (Triassic) of Pennsylvania 49
Earle E. Spamer

Medial Cretaceous carnivorous dinosaur and footprints from New Jersey 53
Donald Baird

The Upper Cretaceous shark *Cretolamna appendiculata* (Agassiz) in the Raritan Formation (Cenomanian) of New Jersey 65
Gerard R. Case

A predator attacks *Sphenodiscus* 69
Frank Bukowski and Paul Bond

The Upper Cretaceous (Campanian, Black Creek Formation) fossil fish fauna of Phoebus Landing, Bladen County, North Carolina 75
Albert J. Robb, III

The biostratigaphy of the Lower Helderbergian formations (Lower Devonian) as exposed along Wallpack Ridge, Sussex County, New Jersey 93
Albert J. Waggenhoffer

Quaternary mammals from the continental shelf off New Jersey 101
William B. Gallagher, David C. Parris, Barbara Smith Grandstaff and Craig DeTample

Preliminary reexamination of the Fish House local fauna and flora (Pleistocene), Pennsauken, Camden County, New Jersey 111
Arthur E. Bogan, Earle E. Spamer, G. Christine Manville, William B. Gallagher and Arthur J. Cain

The vertebrate fauna from the Judith River Formation (Late Cretaceous) of Wheatland and Golden Valley Counties, Montana 127
Anthony R. Fiorillo

Rediscovery of fossil material at the Academy of Natural Sciences of Philadelphia from Edward Drinker Cope's 1893 expedition to the Dakotas 143
Edward Daeschler and Anthony R. Fiorillo

A historic piece of petrified wood from the Triassic of Arizona 149
Earle E. Spamer

A paleontological pilgrimage through Philadelphia, the birthplace of American paleontology. II. With notes on the paleontology of Philadelphia. 153
Earle E. Spamer and Catherine A. Forster

Delaware Valley Paleontological Society. *"Ad amorem rerum fossam"* 165
Edward M. Lauginiger

Preliminary Reexamination of the Fish House Local Fauna and Flora (Pleistocene), Pennsauken, Camden County, New Jersey

Arthur E. Bogan, Earle E. Spamer, G. Christine Manville
Academy of Natural Sciences of Philadelphia
19th and the Parkway, Philadelphia, Pennsylvania 19103

William B. Gallagher
Bureau of Natural History, New Jersey State Museum
205 West State Street, CN-530
Trenton, New Jersey 08625
and
Department of Geology, University of Pennsylvania
240 South Thirty-third Street
Philadelphia, Pennsylvania 19104

Arthur J. Cain
Department of Zoology, University of Liverpool
Liverpool L69 3BX, England
and
International Fellow, Academy of Natural Sciences of Philadelphia

Abstract

The Fish House local fauna and flora is a Late Pleistocene (ca. 100,000 yr B.P.) assemblage from a single freshwater channel-fill deposit on the east bank of the Delaware River in Pennsauken, Camden County, New Jersey. Clays and sandy clays are the dominant matrix of the deposit which has long since been mined out for making bricks. The fossil assemblage is composed of fragments of horse and wolf, fish scales, molds of aquatic gastropods, and compressed plant remains, but the primary component is a series of reasonably well preserved unionid bivalves presumably derived from one bed. Ten species were described in the genus *Unio* and two in the genus *Anodonta*. It is the bivalve component which has been most studied; these fossils and their associated matrix have permitted interpretation of the taphonomic history of the fauna and flora. Measurement and graphic display of the fossil bivalves and modern counterparts show that the bivalve fauna is more representative of South Atlantic Slope faunas than the Interior Basin and North Atlantic Slope faunas to which it has been referred by other workers. The local paleoenvironment at the time the fossiliferous clays were laid down, as interpreted from the plant remains, seems to have been an interglacial cool to warm temperate upland forest.

Introduction

Fish House, a classic paleontological locality on the bank of the Delaware River in Pennsauken, Camden County, New Jersey (Figure 1), is no longer in existence; it has been completely mined out. Although Fish House was a productive locality paleontologically, the existing fossil material is scant in comparison to that derived from other Pleistocene localities in Eastern North America. The fossil material derived from the Fish House excavations, however, comprises an interesting local fauna and flora unique to this locality. Other Pleistocene localities in the region are of different ages and depositional environments.

Fossils from Fish House were first identified in 1868 and have ever since generated much interest and a variety of publications. Clays and sandy clay deposits at Fish House have yielded shells of freshwater bivalves and snails, fragments of fish scales, fragmentary remains of horse and wolf, and a variety of plant fos-

The Mosasaur, 4:111-126
© 1989 Delaware Valley Paleontological Society

sils. Most important scientifically among these remains is the unionid fauna, significant because it represents a unique Pleistocene (ca. 100,000 yr B.P.) large-river freshwater bivalve fauna east of the Appalachian Mountains. The vertebrate remains and fossil wood are the elements used to establish the paleontologically determined age of the Fish House Clay as Pleistocene. We provide a review of the literature and of all recognized Fish House collections, and we emend and correct some published information about these fossils. This report comprises only preliminary remarks for a more thorough examination which will include absolute dating of materials. Repositories for material discussed in this report are: ANSP (Academy of Natural Sciences of Philadelphia), NJSM (New Jersey State Museum, Trenton), and WFIS (Wagner Free Institute of Science, Philadelphia).

History of the Fish House Locality

Edward Drinker Cope reported the first fossils from the Fish House locality; he called it Pea Shore, a name used by boatmen on the Delaware River. Some older maps also record this locality as occurring in "Stockton," or Stockton Township. When Cope visited the site in 1868 it was already long established as a brickworks. As large excavations are quite impossible for a geologist to ignore, Cope investigated the locality and immediately recognized it as a significant one. On June 2, 1868, he presented a report at the meeting of the Academy of Natural Sciences of Philadelphia, a synopsis of which was published in the meeting minutes (Cope, 1868, pp. 157-158). It began:

> "E. D. Cope gave an account of his discovery of the fresh-water origin of certain deposits of sand and clays in west New Jersey, which he found to contain leaves of dicotyledonous trees, ctenoid fish scales, and numerous Unionidae in a tolerably good state of preservation."

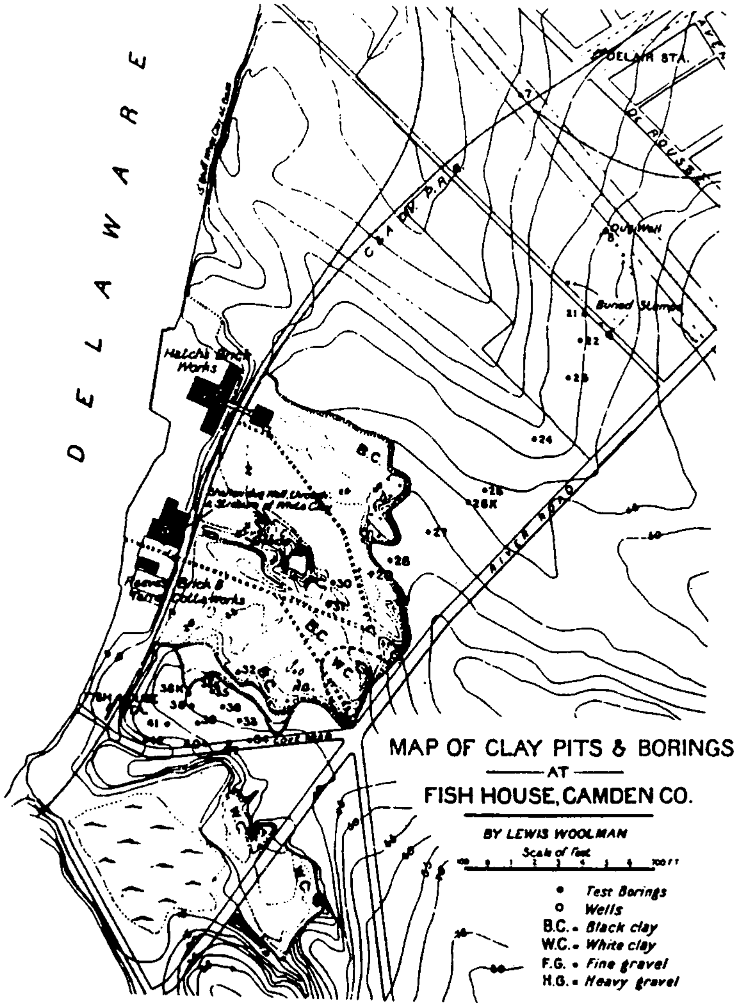


Figure 1. Topographic and geologic map of the Fish House locality (detail from Woolman's map [1897, pl. 11]).

Woolman (1897) published a detailed topographic and geologic map of the area (Fig. 1) which shows two brick factories on the site (Hatch's Brick Works and Reeve's Brick and Terra Cotta Works). These were just north of the Fish House Station of the Camden & Amboy Division of the Pennsylvania Railroad (the tracks of which are still used). Working of the clay for brick probably ceased when the channel-fill deposit was mined out. There is no evidence today of the black clay which is described by previous investigators, and scant amounts of the overlying white clay remain around the periphery of the site (Clark & Miller, 1909, p. 21: they stated that this clay was not being worked at that time). Some brick rubble and the ruins of old brickworks are still apparent over much of the site. A few foundations of buildings and smokestack footings can be seen flush with the ground, and a few rusted implements lie about amidst pieces of coal and miscellaneous rubble. These foundations are not, however, part of the two brickworks shown on Woolman's map, but are in the pit area to the east of the brickworks; they are structures built probably at a later time. Most of the near-surface substrata are disturbed and infilled, and the site is largely overgrown by weeds. The adjacent shoreline of the Delaware River has been altered by the dumping of extensive spoils derived from dredging the main shipping channel. The railroad shown on Woolman's map as hugging the river is today about a quarter to a half mile from the river's edge.

By the 1960s, when the Fish House site was relocated (by Gallagher, for Horace G. Richards of the Academy of Natural Sciences), the excavation was occupied by the Union Paving Company. When the site was again visited (by Gallagher, Bogan, and Spamer) in February, 1988, it was occupied by Glasgow Asphalt, Inc., with a posted street address of 6915 River Road, Pennsauken. Kat (1983) mistakenly reported the site as being occupied today by a sewage treatment plant; the plant is adjacent to the Glasgow property, north of the mined-out pit. The overgrown and rubble-strewn pit is unused, and the remainder of the property contains waste asphalt, asphalt-producing equipment, and a temporary office. Nothing remains of the Fish House Clay.

History of Collections

The first recorded specimens from the Fish House deposits are those Cope (1868) gave Lea (1868a,b) who subsequently described 10 new species of Unionidae (Tables 1, 2). Although Cope also noted leaves and fish scales, we do not know if he collected them (and if he had, where they are today). The partial cranium of *Equus fraternus* Leidy reported by Cope (1870) was noted by Woolman (1897) and Hay (1923) to be missing; it still is. The wolf remains were not located.

Whitfield (1885, 1886) reported that H. Carvill Lewis of Germantown (Philadelphia), Pennsylvania, had amassed a large collection of Fish House unionids and that L. N. Britton had also collected a large number of specimens for the State of New Jersey. Records in the Academy show that Lewis' material was acquired by the Academy in 1898, after Lewis' death. Labels with specimens in the Academy of Natural Sciences' Invertebrate Paleontology collections indicate that H. A. Pilsbry collected some material in 1891 (Pilsbry, 1896), about three dozen specimens (Woolman, 1897). Twenty of the Academy's unionid specimens have labels indicating that William M. Gabb collected them, but there are no dates, and in 1891 Woolman collected four and Pilsbry collected two unionid specimens. In total, we have been able to locate 129 unionid specimens, many without original labels, in the Academy's Invertebrate Paleontology collection; 10 specimens in seven lots at the Wagner Free Institute of Science, Philadelphia; and 41 specimens in the Paleontology collections at the New Jersey State Museum, Trenton. All uncatalogued lots at the Academy were catalogued for this project. There were no uncatalogued lots at either of the two other museums.

The Vertebrate Paleontology collection at the Academy contains the remains of *Equus complicatus* Leidy, collected by Woolman and by J. E. Ives. We are not certain of the whereabouts of the non-equid vertebrate material which has been reported from the locality. Table 1 lists the type and figured material from the Fish House deposits.

We have not seen any of the published specimens of leaves and seeds (Newberry, 1895; Berry, 1907, 1910) said to come from Fish House, nor are we certain of their whereabouts at this time. Nineteen specimens and many small fragments of wood were found in the ANSP Invertebrate Paleontology collection, mixed with an uncatalogued lot of unionid bivalves from Fish House, some of which were stored in an old shoe box. The wood, several pieces of which have been identified to genus (discussed later in this report), has been accessioned into the Paleobotany collection (ANSP 4417-4435).

Stratigraphy and Lithology

The Fish House Clay is interpreted as a cut-off meander type of deposit, composed mostly of silty clays and some sands. It occurs as an abandoned channel of the Delaware River, within the Pensauken Formation (Pleistocene).

When Cope (1868) made his report on the Fish House locality, he noted that

> "The most important part of the deposit consisted of a heavy black clay, which is used for making brick, which rests on a bed of hard laminated clay, with a thin layer of iron-stone between. The clay bed, at one place examined, is 25 feet in thickness, and at from one to three feet from its bottom occurs a bed of fresh water mussels. * * * The beds are from the top of the clay down, conformable, and have a dip of about 25° to the south-east. The upper surface of the

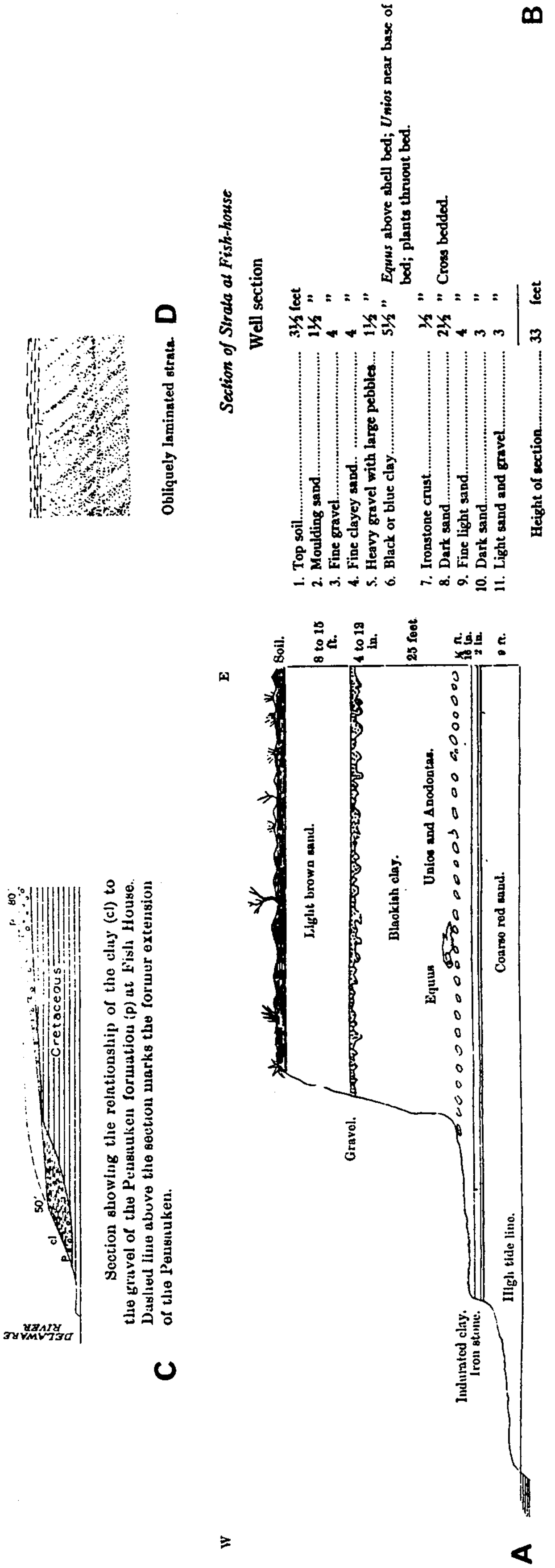

D
Obliquely laminated strata.
B
Section of Strata at Fish-house
Well section
1. Top soil 3½ feet
2. Moulding sand 1½ "
3. Fine gravel 4 "
4. Fine clayey sand 4 "
5. Heavy gravel with large pebbles 1½ "
6. Black or blue clay 5½ " Equus above shell bed; Unios near base of bed; plants thruout bed.
7. Ironstone crust ½ "
8. Dark sand 2½ " Cross bedded.
9. Fine light sand 4 "
10. Dark sand 3 "
11. Light sand and gravel 3 "
Height of section 33 feet
C
80'
Cretaceous
50'
p
cl
DELAWARE RIVER
Section showing the relationship of the clay (cl) to the gravel of the Pensauken formation (p) at Fish House. Dashed line above the section marks the former extension of the Pensauken.
A
E
W
Soil.
8 to 15 ft.
4 to 12 in.
25 feet
½ ft.
18 in.
2 in.
8 ft.
Light brown sand.
Gravel.
Blackish clay.
Unios and Anodontas.
Equus
Coarse red sand.
Indurated clay.
Iron stone.
High tide line.

Figure 2. Stratigraphy of the Fish House locality. This figure reproduces all the known data, combining (A) Cope's (1870) fig. 55, (B) Baker's (1920, p. 203) well section using Woolman's (1897) data, (C) Bascom et al.'s (1909) fig. 4, and (D) Pilsbry's (1896) fig. 1.

Table 1.

Citations for original descriptions, location of type and figured material for Fish House Unionidae. (For remarks on citations for Kat, 1983, see Table 3.)

DESCRIBED TAXA	TYPE	ORIGINAL CITATION AND ILLUSTRATIONS
Anodonta corpulentoides Lea, 1868	ANSP 31525	Lea 1868, p.164; Whitfield 1885, pl. 35, fig. 1 [ANSP 53826]; **this paper, Figure 3** [Type]
Anodonta grandioides Lea, 1868	ANSP 31516	Lea 1868, p.164; Whitfield 1885, pl. 35, figs. 2, 3 [NJSM 7862]; Kat 1983, pl. 3, fig. B, Left [Type]; pl. 3, fig. A, Left [ANSP 70051; uncatalogued when figured by Kat]
Unio alatoides Lea, 1868	ANSP 31521	Lea 1868, p. 164; Whitfield 1885, pl. 33, fig. 3 [specimen not found]; pl. 34, fig. 6 [same specimen]; pl. 33, fig. 4 [ANSP 53828]; Kat 1983, pl. 1, fig. B, Left [Type]
Unio carriosoides Lea, 1868	ANSP 31517	Lea 1868, p. 163; Whitfield 1885, pl. 32. fig. 3 [Type]; Kat 1983, pl. 2, fig. B, Left [Type]
Unio humerosoides Lea, 1868	ANSP 31518	Lea 1868, pp. 163-164; Whitfield 1885, pl. 31, fig. 4 [Type]
Unio ligamentinoides Lea, 1868	ANSP 31522	Lea 1868, p. 164; Whitfield 1885, pl. 31, fig. 1 [Type]; pl. 32, fig. 4 [NJSM 10420]; pl. 34, fig. 8 [same NJSM specimen]
Unio nasutoides Lea, 1868	ANSP 31523	Lea 1868, p. 163; Whitfield 1885, pl. 34, figs. 4, 5 [NJSM 7861]; Kat 1983, pl. 3, fig. C, Left [ANSP 36076]; **this paper, Figure 4** [Type]
Unio praeanodontoides Whitfield, 1885	ANSP 53825	Whitfield 1885, p. 250, pl. 31, fig. 2 [Type]; Kat 1983, pl. 1, fig. C, Left [Type], fig. D, Left [ANSP 53829]
Unio radiatoides Lea, 1868	ANSP 31519	Lea 1868, p. 163; Whitfield 1885, pl. 34, figs. 1 [NJSM 8073], 2 [ANSP 53827], 3 [NJSM 7863]; Kat 1983, pl. 2, fig. C, Left [ANSP 36073]; **this paper, Figure 5** [Type]
Unio rectoides Whitfield, 1885	NJSM 10419	Whitfield 1885, pp. 250-251, pl. 32, figs. 1, 2 [Type]; Kat 1983, pl. 1, fig. E, Left [ANSP 53831]
Unio roanokoides Lea, 1868	ANSP 31520	Lea 1868, p. 164; Whitfield 1885, pl. 31, fig. 3 [ANSP 70086]; pl. 33, figs. 1 [NJSM 10424], 2 [NJSM 10425]; pl. 34, fig. 7 [NJSM 10425]; Kat 1983, pl. 2, fig. A, Left [Type]
Unio subrotundoides Lea, 1868	ANSP 31524	Lea 1868, p. 163; Whitfield 1885, pl. 32, fig. 5 [Type]; Kat 1983, pl. 1, fig. A, Left [Type]

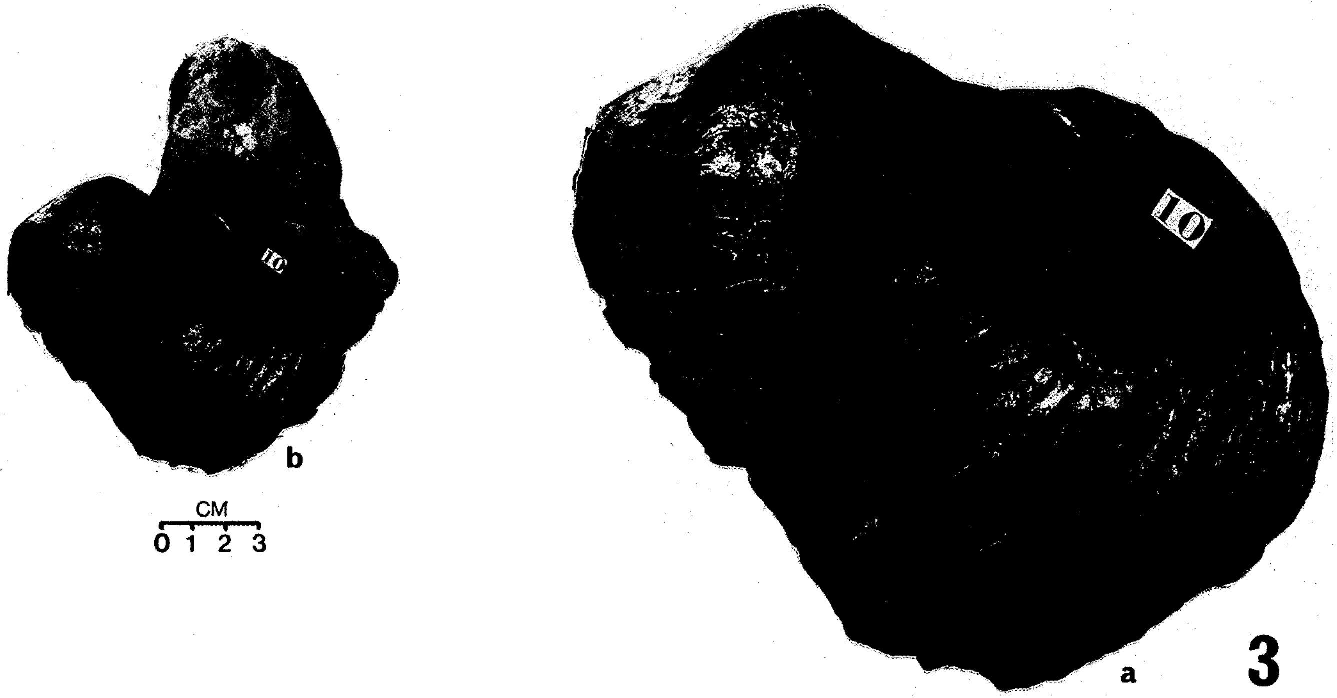
> clay is worn into holes, which are filled by the material of a bed of coarse gravel of little depth, which covers the whole. Above this is a bed of fine sand, varying from six to fifteen feet in thickness to the soil."

Because the Fish House site has long since been completely mined of its clay, we must rely upon published reports in order to establish its stratigraphy. Fortunately, a few very good descriptions were published (Cope, 1870; Pilsbry, 1896; Woolman, 1897). It is Woolman's paper which provides us with what appears to be the most thorough and reliable description of the

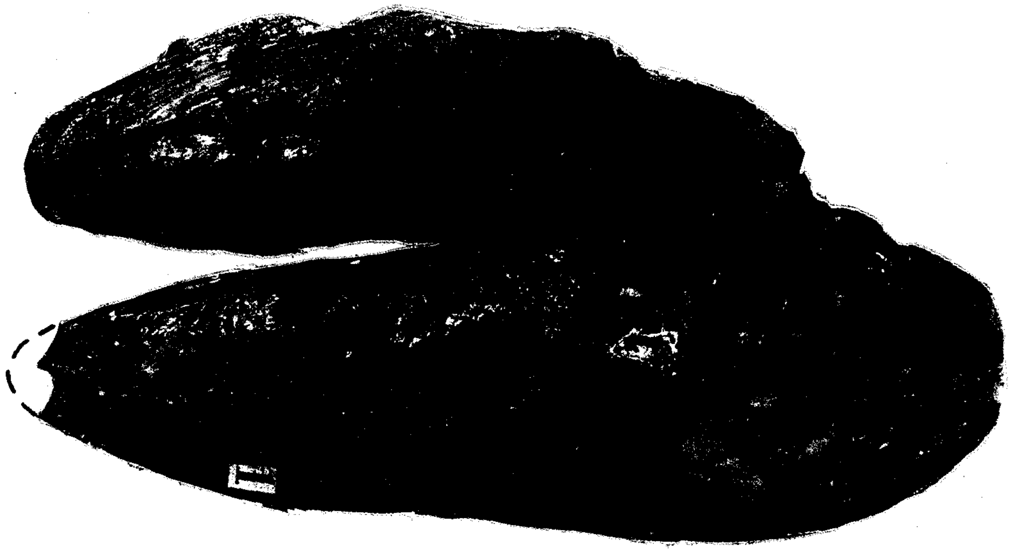
Figure 3. (a) *Anodonta corpulentoides* Lea, 1868, Holotype (ANSP 31525); figured here for the first time. Inset (b) shows entire specimen, consisting of two disarticulated valves filled with matrix.

Figure 4. *Unio nasutoides* Lea, 1868, Holotype (ANSP 31523); figured here for the first time. Dashed line delineates part of the valve apparently present but covered by matrix.

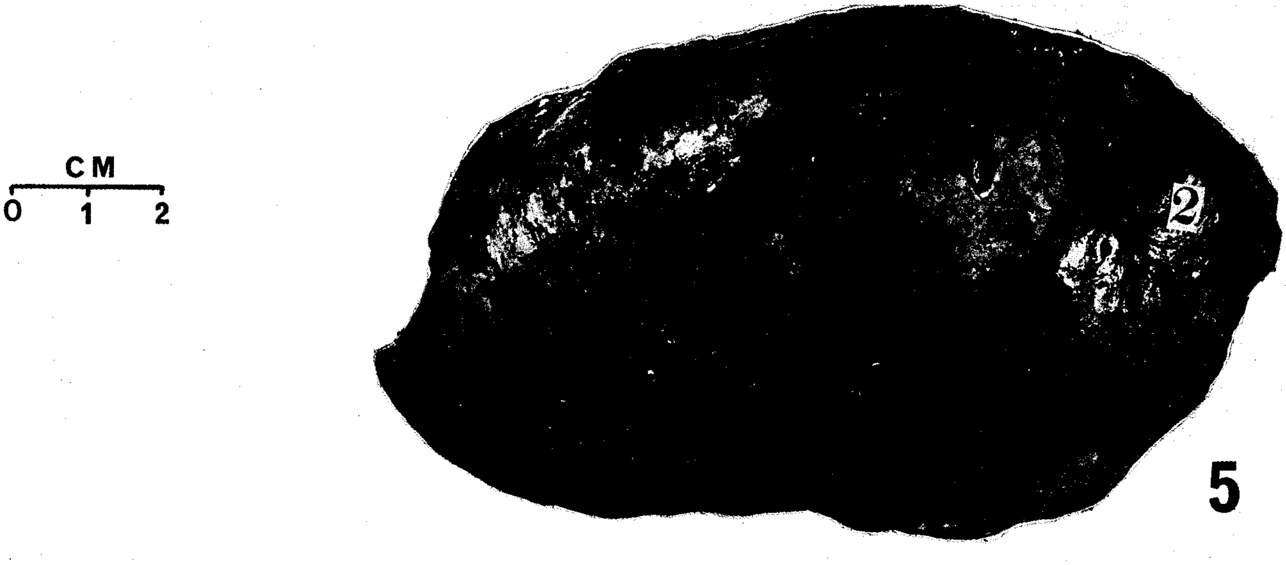
Figure 5. *Unio radiatoides* Lea, 1868, Holotype (ANSP 31519); figured here for the first time.



3



4



5

Table 2.

List of described unionid taxa from Fish House, the comparable recent species and Kat's (1983) identifications

FISH HOUSE TAXA	COMPARABLE RECENT SPECIES (Lea, 1868; Whitfield, 1886)	KAT (1983) IDENTIFICATIONS
Anodonta corpulentoides Lea, 1868	*Anodonta corpulenta* Cooper, 1834*	*Anodonta grandis* Say, 1829*
Anodonta grandioides Lea, 1868	*Anodonta grandis* Say, 1829*	*Anodonta contracta* Say, 1817
Unio alatoides Lea, 1868	*Unio alatus* Say, 1817*	*Leptodea fragilis* (Rafinesque, 1820)*
Unio carriosoides Lea, 1868	*Unio cariosus* Say, 1817	*Lampsilis ochracea* (Say, 1817)
Unio humerosoides Lea, 1868	*Unio humerosus* Lea, 1868	Type = *Lampsilis radiata* (Gmelin, 1791), others = *Elliptio complanata* (Lightfoot, 1786)
Unio ligamentinoides Lea, 1868	*Unio ligamentina* Lamarck, 1819	Type = *Leptodea fragilis* (Rafinesque, 1820)*, others = *Lampsilis cariosa* (Say, 1817)
Unio nasutoides Lea, 1868	*Unio nasutus* Say, 1817 + *U. fisherianus* Lea, 1838	*Elliptio fisheriana* (Lea, 1838), *Elliptio producta* (Conrad, 1836)
Unio praeanodontoides Whitfield, 1885	*Unio anodontoides* Lea, 1834*	Type = *Ligumia nasuta* (Say, 1817), others = *Ligumia recta* (Lamarck, 1819)*
Unio radiatoides Lea, 1868	*Unio radiatus* Gmelin, 1791	*Lampsilis radiata* (Gmelin, 1791)
Unio rectoides Whitfield, 1885	*Unio rectus* Lamarck, 1819*	*Ligumia recta* (Lamarck, 1819)*
Unio roanokoides Lea, 1868	*Unio roanokensis* Lea, 1836 + *U. macer* Lea, 1857	*Elliptio complanata* (Lightfoot, 1786)
Unio subrotundoides Lea, 1868	*Unio subrotundus* Lea, 1831*	*Lampsilis cariosa* (Say, 1817)

*Species with present distribution largely restricted to the Interior Basin

deposits, although Cope's (1870) and Bascom et al.'s (1909) diagrams of the strata are also valuable references; these data are combined in Figure 2. Kat's (1983) review of the Fish House unionid fauna does not discuss stratigraphic occurrence, sedimentological significance of the matrix, or implications of the taphonomic history of the fauna.

Cope's (1868, 1870) descriptions of the Fish House strata include his belief that these deposits were Cretaceous in age, belonging to "Meek and Hayden's Earlier Cretaceous, No. 1" (Cope, 1868, p. 157). His diagnosis was based on lithologic resemblances of the clay to other, definitely Cretaceous, clays in that part of the New Jersey coastal plain. Because the Fish House deposits were so limited in extent, they could not be traced to the other New Jersey exposures. However, when workmen at the pit found horse remains, Cope (1870) had to consider the deposit of "much later age," perhaps Pliocene:

> "Two reasons have a strong bearing on the question. A large part of the cranium of a horse--Equus fraternus of Leidy--was found by the workmen just above the Unio bed, and twenty feet below the top of the clay, evidently in place. The underlying bed of coarse red sand, is in all apparent respects identical with the material of a stratum which underlies the soil over the country 5 and 6 miles to the eastward of Pea Shore, *e. g.*, the town of Haddonfield, which rests unconformably on the Ripley division of the Cretaceous. It does not exist on the surface, so far as I could ascertain from an examination on one line, between these points. It may be the same bed."

The horse specimen is missing, but the species referred to is still a valid species and narrows the biostratigraphic range of the deposit (Kurten & Anderson, 1980), as discussed later in the present report. Lewis (1884) called for an interglacial age for the Fish House deposits, and it is in this period (Pleistocene) that most later workers have placed the deposits. Salisbury (1895) cited the age as "post-Pensauken."

Pilsbry's (1896) comments on the Fish House strata are quite valid even today, and it is he who first published the opinion that the deposits represent fluvial deposits such as those found in a cut-off portion of a river channel. Although we cannot examine the locality ourselves, we can interpret the strata from the published reports and from the matrix still adhering to the unionid bivalve specimens in the collections which have been preserved. The taphonomic implications of the sediments and strata are discussed in the section on taphonomy.

Later time-stratigraphic placements of the Fish House deposits include that of Uhler (1892), who, on sedimentological characters and paleontology, correlated the Fish House deposits with the Albirupean Black Marl. Newberry (1895) correlated the Fish House clays with the Amboy clays, and Hay (1923) indicated the age of the Fish House deposits as belonging to the Aftonian Stage.

The only real clues to the matrices which occurred in the Fish House deposit are the reports of Cope (1868, 1870), Pilsbry (1896), and Woolman (1897) (see Figure 2), and the sediment which still adheres to the unionid bivalves. (None of the vertebrate fossils examined, nor the fossil wood, have matrix adhering to them. The one piece of ?*Acer* sp. from which a small amount of matrix was extracted from a crevice shows a brownish gray [5 YR 5/1] silt.) Usually, the shells are in a matrix of micaceous silty clay, generally pale red (5 R 6/2) to grayish red (5 R 4/2). This fine-grained silty material is what one would expect from a channel-fill (failed evulsion?, cut-off meander?, filled ox-bow?) deposit. Micaceous flakes are almost always visible, and microscopical examination of the matrix likewise almost always shows grains of what we interpret as reworked glauconite. This explains the confusion regarding its supposed Cretaceous age. The type Raritan Formation (Cretaceous) is composed of a series of light-colored sands and clays cut by restricted channel-fill clays that are dark in color, organic-rich, and contain (in thin sideritic layers) mollusk remains. Moreover, in the 19th Century the Delaware River medial Cretaceous Potomac-Raritan-Magothy beds were thought to be strictly correlative to the type Raritan.

A closer examination of the matrix found on the bivalves, although grossly similar, indicates multiple depositional environments. Even though all the published accounts of fossil collecting at Fish House report only a single fossiliferous horizon with a single bed of unionids, the lateral extent over which the specimens were collected was no doubt significant. As a working pit, its appearance and areas of activity must have changed greatly over the few decades during which fossils were obtained there. Consequently, different facies of the channel-fill deposit must have been encountered at various times—and indeed we observe some differences in the material collected by different workers.

High-power microscopical examination of the matrices adhering to the bivalves shows some minor variations among collections; that is, between times of collection in the actively quarried Fish House pit. All specimens examined show muscovite (flakes to 1 mm in size), no doubt derived from the metamorphic basement rocks exposed further north along the Delaware River. Nearly all of the examined specimens contain abundant to minor amounts of a green, lustrous, usually globular mineral which we at this time take to be reworked glauconite, also an abundant mineral in some New Jersey coastal plain sediments which does occur in this way in some Pleistocene deposits. Oxidation also has affected many of the minerals observed in the various fractions; these will require further study.

Some of Cope's specimens show some quartz grains in the silt, while others are devoid of the mineral. What might be pyrite has also been noted in some specimens. Most of Gabb's specimens show well sorted but angular quartz grains in pockets, but some lack it. Some of the dense buff-colored clay is observed adhering to the clay on one specimen (ANSP 36094), the only indication we have for a direct stratigraphic association of the dense clay with the silty brick clay. Some poorly sorted, angular quartz grains were also seen adhered to one of the dense clay specimens collected by Johnson (WFIS 6472). A Woolman specimen (ANSP 70139) has virtually no quartz in its silt-glauconite(?) matrix. A New Jersey State Museum specimen (NJSM 10428[v]) contains no quartz grains. Other NJSM specimens indicate different burial events as affecting the indigenous fauna: specimens that have both valves attached by the hinge but are wide-open are preserved in very silty and sandy silt matrices with a little quartz, very little mica, and virtually no glauconite(?); closed valves are preserved in uniform silt and sandy silt with quartz grains, varying amounts of muscovite, and some glauconite(?).

The colors of the matrix on Cope's specimens are generally grayish red purple (5 RP 4/2) to dark reddish brown (10 R 3/4) [all observations on clean surfaces]. Gabb specimens have grayish red purple to pale red purple (5 RP 6/2) matrix, although one specimen has a grayish orange sand (10 YR 7/4) adhering to the clay. Whitfield specimens have clays of pale red purple (5 RP 6/2) to pale red (10 R 6/2). Woolman's specimens show colors of an undetermined red-brown (the uncertainty is due to the cleanliness of the specimens and the tight closure of double-valved individuals), although some moderate yellowish brown (10 YR 5/4) silty clay is observed on one shell. Johnson's specimens show colors of grayish red purple (5 RP 4/2), pale red purple (5 RP 6/2), and moderate reddish brown (10 R 4/6). The specimens retained by the New Jersey State Museum (collectors unknown) vary in color; examples are pale red (10 R 6/2), yellowish brown (10 YR 5/2), very pale orange (10 YR 8/2), and red purple (5 RP 5/2). All of these modest differences seem to relate to different collecting localities within the Fish House pit, as one would expect from collections made at different times. Some of these differences also seem to affect taphonomic interpretations, as will be noted in following sections of this report.

The two specimens definitely known to have been collected by Pilsbry, as well as a few of the Johnson specimens, are preserved in a uniformly dense grayish orange (10 YR 7/4) to very pale orange (10 YR 8/2) clay. The original label with one Johnson specimen (WFIS 6472) notes that it is from "the lowest stratum," but whether this pertains to the unionid bed at the bottom of the "black clay" or to a stratum beneath that is uncertain. It is obvious that the dense clay is a very different stratum from the rest of the bivalve clays, but its extent in relation to the remaining strata at Fish House is not known; it could have been very limited, quarried only at the time when Pilsbry and Johnson were there in 1891. One specimen, however, has a matrix of silt and sand adhering to it, with a small amount of the dense clay adhering to the matrix. This identifies a close stratigraphic relationship between the unionid bed and the dense clay.

We note that of all these matrices, none are the "black clays" to which earlier workers have referred. However, when the clays are moistened, as they would have been while still in the ground, they do in fact become quite dark red, approaching black. We note on one of the Cope specimens (ANSP 31523) relic fingerprints in the dried clay. To establish better the colors of the clays at the time of collection, we moistened some specimens and compared the colors against the color chart. Some of the Cope specimens when moistened became very dusky red (10 R 2/2) to blackish red (5 R 2/2); Gabb specimens became grayish brown (5 YR 3/2) or grayish red (10 R 4/2); a Whitfield specimen became grayish red (5 R 4/2), and Johnson's specimens very dusky red. NJSM specimens became moderate brown (5 YR 3/4), dark yellowish brown (10 YR 4/2), and dusky red purple (5 RP 3/2).

Bivalves

Cope (1868) gave about 40 unionid specimens collected from the Fish House locality to Isaac Lea, but only the type specimens named by Lea are labelled as having been collected by Cope. Lea (1868a,b) gave a short discussion of the geologic setting and the general state of preservation of the fossils. The fossil bivalves are molds and casts, some showing the shell structure and fine details. Lea (1868a, p. 162) observed that in the assemblage he received, although containing 10 species, none of the individuals have "nodules or folds." The 10 species described by Lea (1868) are all tied by similar name to what he considered their modern counterparts (Tables 1, 2). The types of Lea's taxa are in the Academy of Natural Sciences of Philadelphia (Invertebrate Paleontology) (see Kat 1983, pp. 90-96, pls. 1-3).

Miller (1881, p. 32) remarked that the deposit from which Lea had described 10 species of *Unio* was Miocene, not Cretaceous, in age. However, Miller erred by placing the two species originally described as *Anodonta* in the genus *Unio*. Cope (1870, p. 249) discussed the freshwater clay deposits from Pea Shore (= Fish House) and noted the presence of "Unios and Anodontas of six species." This is four species less than described by Lea (1868a,b). Whitfield (1885, reprinted 1886) redescribed and figured all 10 of Lea's taxa and described two new species (Table 1). Boyle (1883) cataloged all 12 unionid species described from the Fish House locality.

Pilsbry (1896) interpreted the deposits as the result of river action and felt that the Fish House deposits were similar to sloughs along the modern Mississippi River. The similarity in shape of these fossils to modern species as originally indicated by Lea was noted by Pilsbry. However, he (1896, p. 569) pointed out that the remarkable feature of this assemblage of unionids was that certain forms had no modern equivalents in the Atlantic drainages south of the St. Lawrence River. Pilsbry listed six species he felt had their closest affinities with modern species of the Great Lakes system and the northern Mississippi River drainage. Interestingly, he observed that, the Fish House fauna contained none of the "triangular or round unios with heavy teeth" or "no member of the great tuberculate or plicate groups" (Pilsbry, 1896, p. 590). He then suggested the affinities of some of the Fish House species to have been "rather with the Great Lakes system than with the Mississippi or Ohio drainages" (Pilsbry 1896, p. 590).

Woolman (1897, p. 204) echoed Pilsbry's remarks regarding the reconstruction of the Fish House ecology as a "lagoon-like fluvial deposit on the margin of the ancient Delaware River." Woolman (1897, p. 207) mentioned he had recently collected 34 specimens, comprising eight species with 10 specimens of *Anodonta*, and that Pilsbry had collected 36 specimens with the greatest numbers again being specimens of *Anodonta*.

Ortmann (1913, p. 380), in discussing the Alleghenian divide and its influence on freshwater faunas, remarked that the Fish House fossils, probably belonging to a glacial time, were absolutely useless. He felt this was true "because western affinities have been maintained for these species, which surely do not exist." Ortmann went to the trouble to cast modern representative species and could not in most cases find any similarity between the modern correlated species and the Fish House species. He believed that the number of species was inflated and should be reduced from 12 to 3 or 4 and that "there is not a single one which has distinct and unmistakable affinities to any typical western species."

F. C. Baker (1920) provided an extensive review of the available information on the Fish House fossils and agreed with Pilsbry (1896) in his interpretation of the deposits as a lagoon or slough. Baker followed Ortmann (1913) in doubting the western connection of the species as assumed by Lea, Whitfield, and Pilsbry. Baker (1920, p. 206) arrived at a conclusion similar to Ortmann's, that the Fish House Clay fauna

> "...does not represent a recent migration from the west, but an indigenous fauna, perhaps of long occupancy, modified by time and related intimately to the present fauna of the Atlantic drainage... the fauna, while old, was not derived from western stocks (except remotely) but was a typical Atlantic Coast fauna, living in waters warmer than those of the present Delaware, and related intimately to the species now living in the Carolina's and Georgia."

Henderson (1935, pp. 21, 36, 94) listed the unionids from Fish House and the associated literature. His opinion was that the deposit is Pleistocene and the fossils are only representatives of modern species. Richards (1968, pp. 39, 42, 54, 56, 61, 68, 79, 81, 87) recorded the 10 Fish House unionid types described by Lea, but only listed them as types without catalogue numbers. He failed to report the Academy's type of one of Whitfield's Fish House unionid species.

More recently, Kat (1983) reexamined the Fish House unionid types and provided a more detailed examination and analysis of the ventral shell margins. He touched on the problem of variability of shell shape and the problems of species identification of the fossil Unionidae. Kat (1983, p. 86) cited Woodward's (1971) two unionid species from the Cretaceous of Greenland which Woodward thought might have South American affinities, but Kat thought they looked like possible early ancestors of *Elliptio*. However, Kat overlooked the Triassic species assigned to the moderns families Hyriidae and Mycetopodidae from Pennsylvania described by Pilsbry (1921, 1928) and supplemented by Richards (1944, 1948). These unionaceans appear to be morphologically most similar to the modern fauna of South America, with no modern North American representatives.

Table 3.

Errors in Kat's (1983) illustrations of the Fish House Unionidae.

KAT'S FIGURE	KAT'S IDENTIFICATION	ERROR
Plate 1, fig. B, Left	*Unio alatoides* Lea (ANSP 36081)	Figure was printed reversed.
Plate 1, fig. C, Left	*Unio praeanodontoides* Whitfield (ANSP 31523)	Figure is a cutout of the right valve of the pair of valves of the type (53825). The catalog number is the number for the type of *Unio nasutoides*.
Plate 1, fig. D, Left	*Unio praeanodontoides* Whitfield (ANSP 53829)	Figure was printed reversed.
Plate 1, fig. E, Left	*Unio rectoides* Whitfield (ANSP 53831)	Figure was printed reversed.
Plate 2, fig. A, Left	Type specimen *Unio roanokoides* Lea (ANSP 31520)	Figure was printed reversed.
Plate 2, fig. C, Left	*Unio radiatoides* Lea (ANSP 367073)	Catalogue number is 36073.
Plate 3, fig. A, Left	Type specimen *Anodonta grandioides* Lea (ANSP 36075)	The figured specimen is not the type specimen of *A. grandioides* Lea (ANSP 31516, which Kat did figure in his pl. 3, fig. b, left, in error as the type of *A. corpulentoides*). This is a non-type specimen which was uncatalogued when Kat figured it; it is now ANSP 70051. Kat's figure is an oblique view of the specimen.
Plate 3, fig. B, Left	Type specimen *Anodonta corpulentoides* Lea (ANSP 31516)	The figured specimen is the type specimen of *Anodonta grandioides* (ANSP 31516) not *A. corpulentoides* Lea (ANSP 31525). The type of *A. corpulentoides* Lea has not been illustrated by Kat; it is figured for the first time in the present paper (Figure 3).

Kat's identifications of the Fish House unionids are included in Table 1. The ecological scenario Kat (1983) provided was an adjustment of Pilsbry's (1896) comments but Kat credited them to Baker (1920). But Kat's illustrations suffer from several major defects (Table 3): figures printed in reverse, type catalog numbers incorrect, non-type material figured as a type, and confusion of type figures. All of these deficiencies cause one to question the whole set of conclusions as presented by Kat (1983). The first question is why did Kat not figure all of the 12 recognized type specimens if they are so critical in comparisons to modern related faunas. Other problems arise within Kat's identifications. He compared the Fish House fauna with the Recent unionid species he found in the Nanticoke River in Delaware and noted that the local species not present in the Fish House fauna included four species of *Alasmidonta*, *Strophitus undulatus* (Say, 1817), *Lasmigona subviridis* (Conrad, 1835), *Anodonta implicata* Say, 1829, and *Margaritifera margaritifera* (Linne, 1758). He listed two morphologically distinct species of *Anodonta* in the Fish House fauna. However, there are only three species of *Alasmidonta* recorded from the Delaware River (Clarke, 1981); and *Margaritifera* is known only from a small tributary of the upper Schuylkill River, not from the main channel of the Delaware River.

Kat (1983) overlooked additional fossil unionid material, probably of Pleistocene age, described by Morton (1836). Morton had named several unionid species from what he believed to be the coal measures of Ohio but were probably old fluvial deposits of the Ohio River. Morton's type specimens appear to have experienced taphonomic events similar to those shown by the preservation and associated sediments of the Fish House Clay fauna. Morton named the species (types herein listed) *Anodonta abyssina* (ANSP 70140), *Unio petrosus* (ANSP 70141), *U. saxulum* (ANSP 70142), *U. terrenus* (ANSP 70143), and *U. tumulatus* (ANSP 70144, 70145). Additional unidentified material was collected from the banks of the Ohio River in [West] Virginia (ANSP 36069).

Table 4.

Comparative material used in the present reexamination of the Fish House Unionidae. For catalogue numbers of the fossil species, only those for the type specimens are listed (ANSP Invertebrate Paleontology catalogue numbers, except for specimens from New Jersey State Museum [NJSM]); modern comparative material includes all referred lots (ANSP Department of Malacology catalogue numbers).

FISH HOUSE TAXA		MODERN COMPARATIVE MATERIAL AND LOCALITY		
Anodonta grandioides Lea	31516	*Anodonta grandis* Say	346583	Mississippi River, Illinois
			256994	Auglaize River, Kalida, Ohio
Anodonta corpulentoides Lea	31525	*Anodonta corpulenta* Cooper	41200	Canton, Illinois
			41199	Davenport, Iowa
Unio alatoides Lea	31521	*Potamilus alatus* (Say)	42409	Ohio
			126338	Ohio
Unio ligamentinoides Lea	31522	*Actinonaias ligamentina* (Lamarck)	47931	Cincinnati, Ohio
Unio subrotundoides Lea	31524	*Fusconaia subrotunda* (Lea)	97857	Ohio River, Pennsylvania
Unio radiatoides Lea	31519	*Lampsilis radiata* (Gmelin)		
		[male]	126087	Pennsylvania
		[female?]	42355	Susquehanna River, Pennsylvania
Unio humerosoides Lea	31518	*Elliptio humerosus* (Lea)	126993 [Type]	Charlotte, North Carolina
Unio carriosoides Lea	31517	*Lampsilis cariosus* Say	126022	Connecticut River
Unio roanokoides Lea	31520	*Elliptio roanokensis* (Lea)	41378	Altamaha, Georgia
Unio praeanodontoides Whitfield	53825	*Lampsilis anodontoides* Lea (= *L. teres* of Kat, 1983)	126159	White River, Indiana
Unio nasutoides Lea	31523	*Ligumia nasuta* (Say)	347859	Delaware River, Burlington County, New Jersey
			358275	Nantocoke River, Delaware
Unio rectoides Whitfield	NJSM 10419	*Ligumia recta* (Lamarck)	126168	Ohio
			42383	Ohio
Undetermined new(?) taxa				
ANSP 70052		*Anodonta gibbosa* Say	355542	Ocmulgee River, Georgia
ANSP 70053		do.		
ANSP 70122		do.		
ANSP 70123		do.		
NJSM 10428(v)		do.		

The present preliminary reexamination of the Fish House unionids and modern comparative material has been made using specimens in the Academy of Natural Sciences. Table 4 lists all of the modern material used for the preliminary study. The 12 species identified from the Fish House deposit are used in this analysis. A revision of the unionid taxonomic assignments will be addressed in future studies.

Twenty of the comparatively undistorted Fish House specimens were measured. In measuring the specimens, length is taken as the greatest anterior-posterior length with the shell in a position so a line drawn through both adductor muscle scars would be horizontal; height is taken as the greatest distance from the dorsal edge of the umbo to the ventral margin.

Thirteen modern representatives corresponding to the species for which the Fish House species were named (e.g., the Fish House *Unio radiatoides* for the modern *Lampsilis radiata*) were measured and plotted (Figure 6). Thirteen specimens representing the range of modern species reported historically from the Delaware River were also measured and plotted in Figure 6. The Fish House specimens and their modern representatives

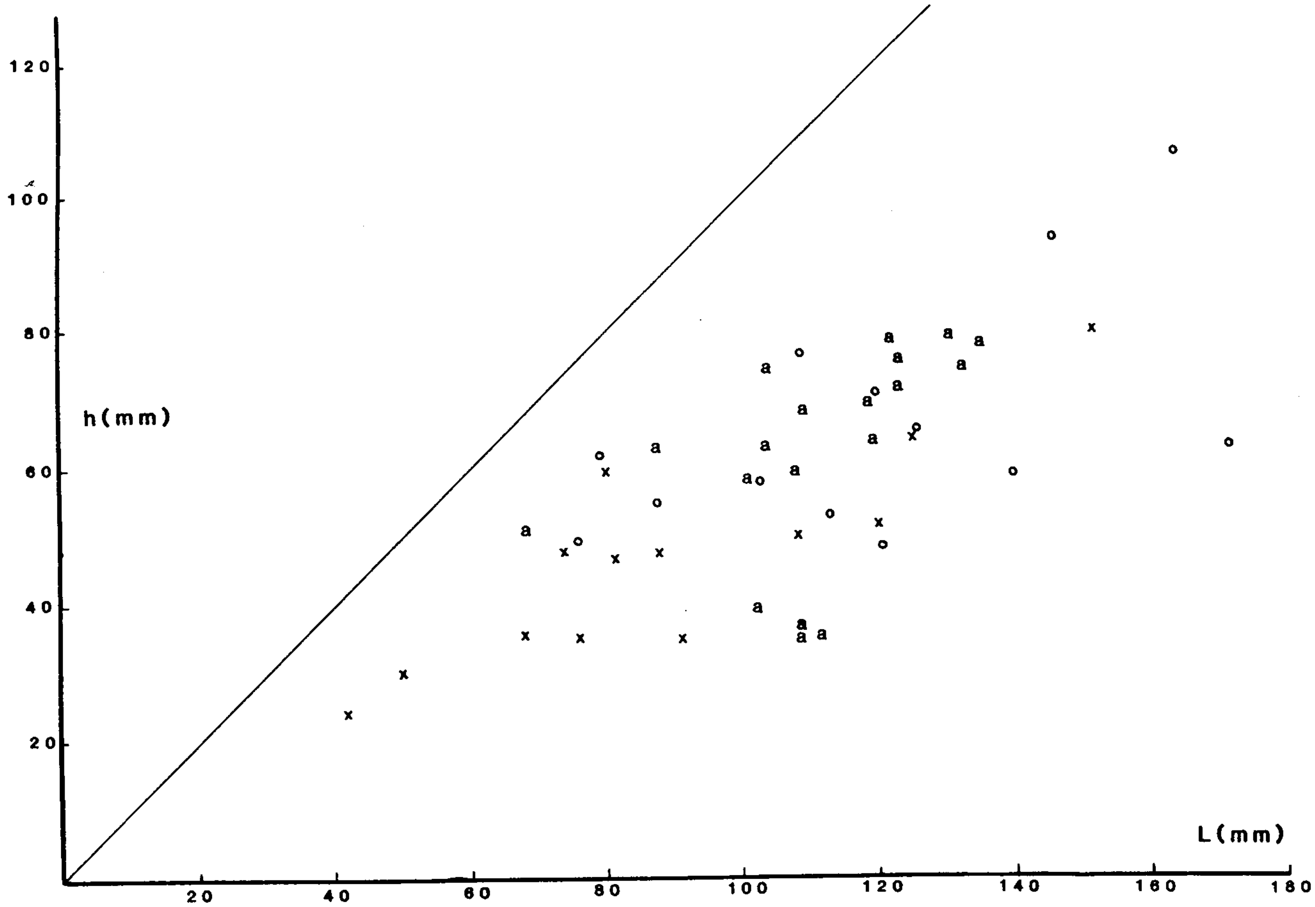


Figure 6. Shell lengths and heights measured on the comparatively undistorted Fish House unionids (a), compared with modern unionid representatives (o) and representatives of the modern Delaware River unionid fauna (x).

cluster together as expected. However, the modern Delaware River fauna and the Fish House fauna are clustered almost completely as separate groups. The major point illustrated by Figure 6 is that the Fish House fauna is composed of large mature shells consistently larger than those of the modern fauna. None of the smaller species characteristic of the modern Delaware River unionids (e. g. *Alasmidonta undulata* (Say, 1817), *Alasmidonta heterodon* (Lea, 1830) were identified in the Fish House fauna. This may be explained by 1) that the smaller elements were not present in the Pleistocene Delaware River unionid fauna, or 2) that this discrepancy is a result of a collecting bias.

The larger shell size of the Fish House fauna may indicate a warmer-water large-river fauna such as found today in North and South Carolina and Georgia. The lanceolate shell shapes of *Unio nasutoides* and *U. rectoides* can be compared to southern forms. It is interesting to note that the internal mold of *U. humerosoides* Lea, 1838, is almost a perfect fit to the inside of the type specimen of the modern *U. humerosus* Lea, 1868 [= *Elliptio complanata* (Lightfoot, 1786)], whose type locality is near Charlotte, North Carolina. A more complete figure of the range of shell shapes which comprise a riverine fauna will be developed later for several of the major South Atlantic Slope rivers to compare with that of the Fish House and other Delaware River unionid faunas.

There appears to be an undescribed species occurring in the Fish House unionid fauna, represented by at least one individual (NJSM 10428[v]), but others might also represent a new taxon (ANSP 70052, 70053, 70122, 70123). The distortion by plastic flow (see the section on taphonomy) does not seem to account for all of the unique features we see in these specimens. If this is a new extinct species, it contradicts Kat's statement (1983, p. 99) that all phenotypes in the Fish House fauna are extant. Kat sided with Lea, Whitfield, and Pilsbry (but not Ortmann and Baker) about the origin of the Atlantic slope unionid fauna and the importance of the Fish House unionid assemblage. The Fish House unionid taxa have been assumed to be modern species, but there is no mention of Fish House taxa in the synopses of North American unionids by Simpson (1900, 1914), Frierson (1927) and Haas (1969).

Gastropods

Three poorly preserved specimens of fresh-water gastropods have recently been found in the Fish House collections at the Academy of Natural Sciences; preliminary identifications are: *Elimia* (= *Goniobasis*) sp. (Pleuroceridae; ANSP 70124, 70125) and *Lioplax* sp. (Viviparidae; ANSP 70127). These are the only Fish House gastropod specimens known to us. The matrix in which the specimens occur is a poorly sorted very sandy clay, by far the sandiest of the preserved Fish House matrices. No mica is seen in the matrix, but reworked glauconite(?) can be observed under the microscope.

Vertebrates

The Fish

Cope (1868, 1870) reported fish scales from the Fish House matrix, but we are unable to comment on them because they evidently were not collected. At best, we can only say that the occurrence of fish scales is not unexpected. But Woolman (1897, p. 211) repeated an unverifiable occurrence of an unidentified fish impression near Fish House:

> "Corroborative of the fish scales we have been informed by a resident of Delair that in connection with the finding of 'clams' (Unionidae) near the bottom of the black clay in digging a well on premises occupied by him some years since, he had obtained the impression of a fish, and that he had given away the specimen to a geologist who had called on him shortly afterward."

The Wolf

Remains of wolf were informally reported by Lewis (1884) and (citing Lewis) Woolman (1897). However, no one has published a binomen for the wolf and the whereabouts of the material is unknown. A search of the collections at the Academy of Natural Sciences failed to find these bones. Woolman's (1897) report is about the best report we have of the wolf from Fish House (p. 211):

> "We have, however, recently been reliably informed that for the purpose of study Prof. Lewis had collected together at one time in some trays at the Academy of Natural Sciences, of Philadelphia, some specimens of Unionidae . . . ; also, the skull of a horse, and some bones not those of a horse, and that he and Prof. Cope held a consultation about the same, the bones other than those of the horse being pronounced by Prof. Cope to be those of a wolf."

Woolman added, in a footnote, that the horse skull "was probably the specimen before referred to as having been obtained by Prof. Cope."

The Horses

Equus complicatus (reported by Woolman, 1897) is biostratigraphically a long-ranging species (late Irvingtonian to late Rancholabrean Land Mammal Stages). The specimens are ANSP 11443 (a patella collected by J. E. Ives) and ANSP 11484 (maxillary fragments with five or six molar fragments, collected by Woolman, noted as coming from a juvenile individual). *Equus fraternus* (reported by Cope, 1868, 1870) is much more dateable; Kurten and Anderson (1980) stated that it ranges from Sangamonian to Wisconsinan time, a more restricted biostratigraphic range placing it approximately within the last several hundred thousand years (Sangamonian absolute dating is still controversial). The specimen of *E. fraternus* has been missing for some time, as Woolman (1897) and Hay (1923) both noted its absence. A search just made of the ANSP collections has again failed to find it. The chief difference between *E. complicatus* and *E. fraternus* is that the upper teeth of *E. fraternus* are more slender. The two may be different forms of an evolving population. Another entry in the ANSP Vertebrate Paleontology catalogue (11483) lists a coronet of *Equus* sp. collected by Woolman at Fish House, but the specimen could not be found.

Plants

The Fish House Clay previously yielded abundant flattened wood fragments and occasional intact leaf impressions and peat deposits (Newberry, 1895; Woolman, 1897; Berry, 1907, 1910). Although the age of the section has not been determined by absolute dating techniques, the wood, leaf, and seed components suggest Pleistocene age. The collection of wood is in the Paleobotany collection of the Academy of Natural Sciences (ANSP 4417-4435). We do not know who collected this material, but H. Carvill Lewis is credited with discovering fossil wood at the site; the stratum of the Fish House deposits from which the wood was derived is also unknown. However, Berry (1907) noted that in one specimen retrieved from Fish House a leaf was partially obscured by a unionid shell; hence at least some of the plant material can be placed at the unionid-bearing level of the deposit (see Figure 2). Additionally, Woolman (1897) and Baker (1920, p. 203, using Woolman's data) indicated that plant remains occurred throughout the black clay beds.

The Academy's wood pieces from Fish House were housed with uncatalogued Fish House unionids in the Academy's Invertebrate Paleontology collection (now catalogued). The wood is clean, but a small amount of matrix was extracted from a crevice in one piece. This matrix does not match the silty clay deposits which fill and adhere to the unionid specimens; however, it does resemble the sandy matrix which can be seen adhering to the clays on a few of the unionids. However, if the wood represents driftwood detritus, the matrix could have been accumulated in the crevice anywhere on the wood's journey to Fish House.

As shown in Table 5, the known flora of the Fish House Clay can be referred to modern genera. The genera reported thus far are similar to those of modern and Holocene conifer-hardwood and mixed hardwood forests of eastern North America. These remains seem to resemble Pleistocene rather than late Cretaceous taxa even if one bases this assumption only on plant genera without reference to faunal remains or stratigraphic position. A tiny sliver of fragile lignitic wood (2 mm long) was found in the matrix associated with the freshwater gastropods noted above.

The wood from the Fish House Clay has not been identified to species; indeed, generic identifications (even with adequate reference materials) may be hindered by the degree of compression. Woolman's (1897) and Berry's (1907, 1910) analyses, together with the identified material at hand (Table 5), suggest an interglacial cool to warm temperate upland forest near the Fish House site when the fossiliferous clays were deposited. This conclusion is based upon recent data derived from the pollen record of eastern North America (McAndrews and Manville, 1987; Delcourt and Delcourt, 1987).

At the time the collections were made, pollen analysis was not a standard tool in evaluating regional vegetation. A common feature of Pleistocene interglacial pollen stratigraphy in eastern North America is the similarity to that known for the Holocene, particularly the last 14,000 years. The inferred climate and flora of Fish House Clay are similar to that documented for eastern North America. In contrast, material from the Long Branch site

(Berry, 1910) with seed remains of *Taxodium* sp., *Pinus* cf. *taeda*, *Juniperus virginiana*, *Carya glabra*, *Quercus* sp., *Vitis* sp., and *Nyssa* sp. indicate a warm temperate flora, probably on a coastal plain or near an embayment (according to the synthesis by Delcourt & Delcourt, 1987). *Taxodium distichum* from Philadelphia (Richards, 1931, 1960; Spamer & Forster, 1989) has been dated at probably 42,200 years B.P. (Richards, 1960).

The one leaf impression reported by Newberry (1895, p. 109, pl. 15, fig. 5), which he identified as the new species *Tillaephyllum dubium*, is unfortunately from an undocumented stratum in the Fish House locality. Woolman (1897, p. 213) remarked,

> "We have ascertained that the leaf certainly came from the locality and was collected by Dr. L. N. Britton, but after a personal interview with Dr. Britton and an examination of the matrix of the specimen which is . . . though badly preserved . . . we find it is impossible to determine whether this leaf is from the black or the [overlying] white clays of the vicinity."

There probably is enough Fish House fossil wood in the Academy's collection to enable us to obtain an absolute age for that material. Even if the stratigraphic position of none of the Fish House floral material can be pinpointed, we do know that the Fish House deposit was of limited geographic extent and probably of limited extent in time.

Taphonomy

The taphonomic history of the Fish House fauna and flora is not easily determinable because we have no precise record of how the fossils were oriented in relationship to the various sediments, nor do we have an unbiased sample of the total fauna and flora. We must therefore restrict our view to observations of the extant material in the three collections known to us.

Equid remains from Fish House are in very good condition. They show little wear due to abrasion or other post-mortem damage to the exposed bone. There is no compression or obvious distortion of this material. The fish scales alluded to by Cope (1868, 1870) have not been found in collections. As we are uncertain that this material was in fact ever collected, only reported in print, we might suppose that the material was in too poor condition to be successfully collected. If so, this would indicate the chemical action of ground water particularly, and we have presented some evidence that in fact the Fish House Clay was at least a wetted clay.

Plant remains, as represented by the wood in the Academy's Paleobotany collection, are compressed but otherwise not badly deformed. They have suffered little desiccation, even after drying. The compression is that normally expected soon after burial of such cellular material as wood. The leafy material like that reported by Newberry (1895) seems to have been preserved

Table 5.

Plant remains from the Fish House Clay, as reported in the literature and as determined from preliminary identifications of ANSP specimens in hand[1] [ANSP paleobotany catalogue numbers are givenb).

	BOTANICAL COMPONANT OF IDENTIFIED MATERIAL		
IDENTIFICATION	WOOD/BARK	LEAVES	SEEDS
Acer sp.	See note 2	Fragments (Woolman, 1897; Berry, 1907)	
Nyssa sylvatica			Berry (1907)
Tilia sp., cf. *T. americana*[3]		Berry (1907), Newberry (1895)	
Quercus sp. (ring porous wood)	ANSP 4418	Woolman (1897)	
Betula sp./*Ostoya* sp. (diffuse porous wood)	Woolman (1897); ANSP 4417		
Pinus sp.	Woolman (1897)		
Conifer indet.	Woolman (1897)		
Peats (flattened plant stems, trunks)	Woolman (1897)		

---

[1] Tentative identifications by G. C. Manville.

[2] Six specimens of *Acer* sp. have been pieced together to form a broken, compressed, partial log: ANSP 4419 + 4421 + 4424 + 4431 + 4432 [the last lot contains two specimens].

[3] Originally identified as *T. dubium*.

Table 6.

Distribution of Fish House Unionidae according to state of preservation of valves (no. of individuals).

	COLLECTION				
State	ANSP	NJSM	WFIS	Total	% of Total
Closed	105	21	6	132	73.3
Gaping	12	10	0	22	12.2
Flat Open	3	8	3	14	7.8
Single	9	2	1	12	6.7
TOTAL	129	41	10	180	100.0

as impressions on bedding planes within the unconsolidated clay. Compression of the wood was noted by Woolman (1897, p. 212); he reported that "One specimen measured was 5/8 of an inch in the shorter diameter and 2 3/4 inches in the larger diameter" and that "In another the two diameters were respectively 3 and 8 inches."

The best insight into taphonomic processes at Fish House is obtained by examining the unionid assemblage. We have examined the 180 specimens at the Academy of Natural Sciences, the New Jersey State Museum, and the Wagner Free Institute of Science. These examinations can be combined with comments made by Whitfield. Whitfield (1885, p. 244) observed that "the valves have usually been preserved in contact" and "have been imbedded vertically or obliquely in the clays." The vertical or oblique orientation of the fossils in the substratum with the posterior end of the shell uppermost indicates that the clams were in life position when they were buried. Whitfield noted that many specimens were found with the two valves closed; this might indicate that they were in life posture. In fact, 73 percent of the 180 specimens we examined have closed valves. Some faint laminae seen in the matrix on a couple of specimens might be minor accumulations of sediment against the sides of the shell, rather than actual bedding of the Fish House Clay, so we are unable to restore any of them to the positions in which they were found by their collectors.

All 180 located specimens were examined to determine valve positions and were classified as (1) specimens with both valves present and quite close together as in life, presumably living at the time of burial, (2) those with gaping valves, those opened widely but not flat open, (3) flat open valves attached at the ligament, and (4) single, isolated valves. Gaping valves are interpreted as of animals dying or dead at the time of burial. The flat open and single valves are interpreted as having been dead before burial. Table 6 lists the distribution of the total sample according to taphonomic category.

At some horizons in the lower part of the Judith River Formation (Late Cretaceous) at Dinosaur Provincial Park, Alberta, Canada, channel deposit bedding planes are covered with the gaping fossil shells of unionids. Koster et al. (1987) have interpreted this mode of occurrence to indicate mass mortality after upward escape from sediment burial. Death may be due to a drop in water level and subsequent aerial exposure; the shells were then buried before decay of the ligament uniting the valves. A similar scenario is plausible for the fossiliferous beds of the Fish House Clay.

If we look at all of the Fish House bivalves, we can see a correlation between sediment type and how the valves are found in relation to one another. The dense buff-colored clays yielded almost exclusively long, narrow shells found flat open or as single valves. The silty clays with some minor sands yielded all of the broad, rounded shells which were closed or gaping; the gaping shells are filled with silts not associated with sands. We feel that these are indicators of living environments and silt-infilling after possible initial escape from burial.

That most of the Fish House unionds were living, a life assemblage, is indicated by the predominance of the specimens with closed valves (interpreted as life position)(Table 6). The presence of worm feeding traces on the outside surfaces of some fossil internal molds is interpreted as an indication that some organic material remained after the softparts of the unionid was replaced by silt/clay. Similar evidence of burrowing into internal molds within the shell can be seen in dead modern unionids in which the softparts have been replace by mud.

Several of the valves (e.g., ANSP 70080, 70112) have circular spots in the nacre, similar to those commonly seen in modern unionids and described by Clark & Wilson (1912, p. 43) and Coker (1915). The modern spots are attributed to disturbances in the riverine ecology or to pollution (Rosenberg & Henschen, 1984). The spots observed on the Fish House specimens may be attributed to the muddy environment.

Because we see slight lithologic differences between times of collection, as the open pit was quarried further, it is apparent that subtle changes were occurring during the time of deposition of the Fish House deposits. This is an expected condition within a cut-off channel being filled by periodic overbank flooding and associated deposition of various sizes of sedimentary particles. Only the deposition of the very dense clay stratum seems to have had a profound effect on the unionid fauna, as inferred from the proportionately large number of dead shells; but, unfortunately, our sample size is too small to make any remarks beyond the obvious one that in such a suffocating environment we would not expect many survivors.

The final taphonomic event--that of collection--is a factor of unknown significance in our interpretation of the Fish House fauna and flora. We suspect a bias only for the "best" material. Vertebrate remains may have been scarce enough so that just about anything found would have been collected. The few fish scales which Cope (1868, 1870) noted were probably just that. Scraps of fish were not generally deemed as important as, say, pieces of evolutionarily significant horses; this factor may account for the attention paid to the equid remains (Cope, 1870; Woolman, 1897; Baker, 1920; Hay, 1923). Plants, although always popular aesthetically, tend to be acquired but often not actively studied. Only Newberry's (1895) and Berry's (1907, 1910) Fish House leaves and seeds have been studied; the wood preserved in the Academy's collection was apparently not seen as worthy even of curation until now. The bivalve fauna is comprised almost entirely of whole individuals. We do not know what sort of scraps were tossed away in the field; perhaps even the small (juvenile?) specimens were not saved. It seems unusual to us that we should find a fauna entirely of very mature, whole individuals. (We note, though, that one juvenile individual of ?*Anodonta* sp., ANSP 70126, was found in the matrix associated with the freshwater gastropods mentioned earlier in this report.) It is possible, too, that some of the specimens might have been obtained from spoil piles, having been discarded by workers at the brickworks just as they would have thrown out gravel and cobbles. This kind of biased collecting is not unusual for turn-of-the-century workers; it is unfortunate only to investigators today. Sadly, we cannot make a new collection now.

The Fish House unionids are preserved in several degrees of completeness. Very little if any original external shell material exists on the specimens we have examined. The shell material observed on many specimens is apparently the nacreous(?) layer. Except for the few preserved as single valves or flat open pairs of valves, nearly all specimens are preserved as internal molds, usually with at least part of the nacreous layer. We identified 13 specimens which are composed of internal molds only (without outer layer), 3 specimens preserved as external casts only, and 1 specimen preserved as an internal mold with its external cast. Our interpretation of specimens carrying an outer shelly layer is liberal, including specimens which retain only partial coverings of the layer. One specimen (ANSP 36090) is a flattened but otherwise complete individual that is preserved with its external cast in a block of matrix.

Comparisons of the fossil material with modern material (Table 4) is complicated by deformation of most of the fossil shells. The type specimens of Lea and Whitfield, and the specimens collected by W. M. Gabb, are all for the most part well-preserved shells. Some are incomplete or broken, but, except for some compression in the plane of the valves, they do not have the appearance of having been strongly deformed. All of these specimens are well lacquered, so it is difficult to tell whether the apparent shell material is in fact shell. These specimens comprise the best preserved of all the Fish House unionids. At this time no testing has been made on these specimens because most of them are types.

We are uncertain as to the kind of deformation which has affected many specimens; there appears to be a variety of effects. Some shells are shattered but otherwise intact, as indicated by networks of breaks across the entire shell; some are collapsed completely, a few with severe breaks; some appear to have been shattered and then slowly deformed, skewing the profile of the shell in one plane; some appear to have been plastically deformed since they show some skewing but fail to exhibit damage to the outer layer. Only the single valves and wide-open valves are preserved more or less without deformation; this might give us a clue as to the direction of stress in the clay deposits.

We assume that most of the complete individuals were in life posture when buried, for the reasons discussed above. The skewed appearance of the more inflated species (like the *Anodonta* specimens and the ?new species) does not appear on the compressed species; hence, we assume that stresses were not so severe as to affect the flatter kinds of shells. The strongly formed umbones seen in these specimens seem to have acted as obstacles against which the stress field in the clay acted. The obvious result was plastic deformation, skewing the umbones and modifying some of the adjacent slope angles. The stress field seems to have been active in directions normal to the orientationntation of the shells buried in life postures, rather than in the vertical direction which would imply overburden pressures. Such laterally directed stresses would be expected if the clay were slumping along surfaces between beds within the channel deposit. Plastic deformation of the clay itself, with movement more or less along bedding planes, would have similarly affected the inclusions within the clay: the unionids were most affected, while flat-lying pieces of wood and resistant pieces of bone were less affected.

Continued Study

Further investigations intended for the Fish House fauna and flora include absolute dating. Carbon-14 methods can indicate ages younger than 40,000 yr B.P. Hydroxyapatite dates on bone material might provide greater accuracy if the site proves to be younger than 40,000 yr; however, the scarcity of existing material might preclude sacrificing portions of specimens for the sake of dating. Amino acid racemization dating of shell fragments may be able to provide a date from shell fragments (e.g., Miller et al., 1987). Pollen studies can confirm the regional pollen assemblage, and identification of seeds, leaves, wood, and other plant remains could establish the local environment at the time of deposition. Diatoms from matrix filling the unionid clams can also serve as indicators of paleoenvironment. However, the presence of either pollen or diatoms in the matrix has not yet been investigated.

Acknowledgements

We wish to thank the following people for providing us with data, materials, and useful discussions: Edward Daeschler and George M. Davis (Academy of Natural Sciences of Philadelphia), John Graham (Wagner Free Institute of Science), David C. Parris (New Jersey State Museum), and Walter Sage (American Museum of Natural History). Paul W. Parmalee (McClung Museum, University of Tennessee, Knoxville) and Barry Miller (Dept. of Geology, Kent State University, Kent) critically reviewed this manuscript.

References Cited

Baker, F. C. 1920. *The life of the Pleistocene or Glacial Period, as recorded in the deposits laid down by the great ice sheets*. University of Illinois.

Bascom, F., W. B. Clark, N. H. Darton, H. B. Kummel, R. D. Salisbury, B. L. Miller, & G. N. Knapp. 1909. Description of the Philadelphia district. *In*: U.S. Geological Survey, *Geological atlas of the United States, Philadelphia Folio, no. 162.*

Berry, Edward W. 1907. A *Tilia* from the New Jersey Pleistocene. *Torreya*, 7(4):80-81.

-------. 1910. Additions to the Pleistocene flora of New Jersey. *Torreya*, 10(12):261-267.

Boyle, C. B. 1893. *A catalogue and bibliography of North American Mesozoic Invertebrata*. U.S. Geological Survey, Bulletin 102.

Clark, H. W., & C. B. Wilson. 1912. *The mussel fauna of the Maumee River*. U.S. Bureau of Fisheries, Document 757, 72 pp.

Clark, W. B., & B. L. Miller. 1909. Coastal Plain area. *From*: F. Bascom et al., Description of the Philadelphia district. In: U.S. Geological Survey, *Geological Atlas of the United States, Philadelphia Folio, no. 162.*

Clarke, Arthur H. 1981. *The Tribe Alasmidontini (Unionidae: Anadontinae), Part 1*: Pegias, Alasmidonta, *and* Arcidens. Smithsonian Contributions to Zoology, no. 326, 101 pp.

Coker, R. E. 1915. *Mussel resources of the Tensas River of Louisiana*. U.S. Bureau of Fisheries, Economic Circular 14, 8 pp.

Cope, E. D. 1868. [Remarks on the fresh-water origin and relations of certain sands and clays in New Jersey, Maryland, and Virginia.] *Academy of Natural Sciences of Philadelphia, Proceedings*, 20:157-158.

-------. 1870. Synopsis of the extinct Batrachia, Reptilia and Aves of North America. *American Philosophical Society, Transactions*, new series, 14:1-252. ["The fresh-water clays of the Pea Shore", pp. 249-250].

Delcourt, Paul A., & Hazel R. Delcourt. 1987. *Long-term forest dynamics of the temperate zone: a case study of late-Quaternary forests in eastern North America*. New York: Springer-Verlag, 437 pp. (Ecological Studies, Analysis and Synthesis, vol. 63.)

Doyle, J. A. & L. J. Hickey. 1976. Pollen and leaves from the mid-Cretaceous Potomac Group and their bearing on early angiosperm evolution. *In*: C. B. Beck, ed., *Origin and early evolution of angiosperms*. New York: Columbia University Press, pp. 139-206.

Frierson, L. S. 1927. *A classified and annotated checklist of North American Naiades*. Waco, Texas: Baylor University, 111 pp.

Haas, Fritz. 1969. Superfamilia Unionacea. *In*: *Das Tierreich*. Berlin: Lief. 88:i-x, 1-663.

Hay, Oliver P. 1923. *The Pleistocene of North America and its vertebrated animals from the states east of the Mississippi River and from the Canadian provinces east of longitude 95°*. Carnegie Institution of Washington, Publication No. 322, 499 pp.

Henderson, J. 1918. The nomenclature and systematic position of some North American fossil and Recent mollusks. *Nautilus*, 32(2):60-64.

-------. 1935. *Fossil non-marine mollusca of North America*. Geological Society of America, Special Paper 3, vii + 313 pp.

Kat, Pieter W. 1983. Fossil evidence from Fish House clays for the origin and changes in species composition through time of the northern Atlantic Slope unionid fauna (Mollusca: Bivalvia). *Academy of Natural Sciences of Philadelphia, Proceedings*, 135:85-101.

Koster, E. H., P. J. Currie, D. Eberth, D. Brinkman, P. Johnston, & D. Braman. 1987. *Sedimentology and paleontology of the Upper Cretaceous Judith River/Bearpaw Formation at Dinosaur Provincial Park, Alberta*. Drumheller, Alberta: Tyrell Museum of Paleontology, 128 pp.

Kurten, Bjorn, & Elaine Anderson. 1980. *Pleistocene mammals of North America*. New York: Columbia University Press, 442 pp.

Lea, Isaac. 1868a. Descriptions of Unionidae from the Lower Cretaceous formation of New Jersey. *Academy of Natural Sciences of Philadelphia, Proceedings*, 20:162-164.

-------. 1868b. Descriptions of Unionidae from the Lower Cretaceous formation of New Jersey. [In a reprint of papers by the author, pp. 30-32.]

Lewis, H. Carvill. 1884. Field lectures in geology. *Public Ledger* (Philadelphia newspaper), April-June 1884 [in installments].

McAndrews, J. H., & G. C. Manville. 1987. Ecoregions ca. 1500 A.D. *In*: R. C. Harris, ed., *The national historical atlas of Canada. Vol. 1, From the beginnings to 1800*. University of Toronto Press, pls. 17, 17A.

Miller, Barry B., William D. McCoy, & Ned K. Blever. 1987. Stratigraphic potential of amino acid ratios in Pleistocene terrestrial gastropods: an example from west-central Indiana, U.S.A. *Boreas*, 16:133-138.

Miller, S. A. 1881. The Caenozoic Age or Tertiary Period. *Cincinnati Society of Natural History, Journal*, 4(1):3-46.

Morton, Samuel G. 1836. Appendix. Being a notice and description of the organic remains embraced in the preceding [sic] paper. [Appendix to: S. P. Hildreth, Observations on the bituminous coal deposits of the valley of the Ohio, and the accompanying rock strata; with notices of the fossil organic remains and the relics of vegetable and animal bodies, illustrated by a geological map, by numerous drawings of plants and shells, and by views of interesting scenery.] *American Journal of Science*, 29:149-154, pls. 1-31.

Newberry, John Strong. 1895. *The flora of the Amboy clays; a posthumous work edited by Arthur Hollick*. U.S. Geological Survey, Monograph 26, 260 pp.

Ortmann, Arnold E. 1913. The Alleghenian Divide, and its influence upon the freshwater fauna. *American Philosophical Society, Proceedings*, 52(210):287-389, pls. 12-14.

Pilsbry, Henry A. 1896. Geology of the mussel-bearing clays of Fish-House, New Jersey. *Academy of Natural Sciences of Philadelphia, Proceedings*, 48:567-570.

Richards, Horace G. 1931. The Subway Tree--A record of a Pleistocene cypress swamp in Philadelphia. *Bartonia*, no. 13, pp. 1-6, pl. 1.

-------. 1944. Fossil mollusks from the Triassic of Pennsylvania. *Pennsylvania Academy of Science, Proceedings*, 18:69-72.

-------. 1948. Fossil mollusks from the Triassic of Pennsylvania. *Notulae Naturae*, no. 206, 4 pp.

-------. 1960. The dating of the "Subway Tree" of Philadelphia. *Pennsylvania Academy of Science, Proceedings*, 34:107-108.

-------. 1968. *Catalogue of invertebrate fossil types at the Academy of Natural Sciences of Philadelphia*. Academy of Natural Sciences of Philadelphia, Special Publication 8, 222 pp.

Rosenberg, Gary D., & Max T. Henschen. 1984. *The effects of pollution on growth of midwestern mussel shells*. Purdue University, Water Resources Research Center, West Lafayette, Indiana, Technical Report 168, 13 pp.

Salisbury, Rollin D. 1895. The Pensauken formation. *New Jersey Geological Survey, Annual Report*, Sect. 4, pp. 105-118.

Simpson, Charles T. 1900. Synopsis of the Naiades, or pearly fresh-water mussels. *U.S. National Museum, Proceedings*, 22(1205):501-1044.

-------. 1914. *A descriptive catalogue of the Naiades, or pearly fresh-water mussels*. Detroit, Michigan: Bryant Walker, 1540 pp.

Spamer, Earle E., & Catherine A. Forster. 1989. A paleontological pilgrimage through Philadelphia, the birthplace of American paleontology. II. Including notes on the paleontology of Philadelphia. *The Mosasaur*, 4:153-164 [this issue].

Uhler, P. R. 1892. Albirupean studies. *Maryland Academy of Sciences, Transactions*, new series, 1 [1888-1900]:185-202 [1901].

Wanner, H. E. 1921. Some faunal remains from the Trias of York County, Pennsylvania. *Academy of Natural Sciences of Philadelphia, Proceedings*, 73:25-37, pls. 1-3.

------. 1926. Some additional faunal remains from the Trias of York County, Pennsylvania. *Academy of Natural Sciences of Philadelphia, Proceedings*, 78:21-28, pl. 3.

White, C. A. 1883. A review of the non-marine fossil Mollusca of North America. *U.S. Geological Survey, 3rd Annual Report*, pp. 405-486, pls. 1-32.

Whitfield, Robert P. 1885. Brachiopoda and Lamellibranchiata of the Raritan clays and greensand marls of New Jersey. *U.S. Geological Survey, Monograph* 9, 338 pp., 35 pls. [See Sect. 7, Unionidae from the clays at Fish House, Camden County, pp. 243-252. Republished 1886 as Geological Survey of New Jersey, Vol. 1, Paleozoic, Cretaceous and Tertiary.]

Woodward, F. R. 1971. Descriptions of two new species of fossil freshwater mussels (Unionidae) from Greenland. *Journal of Conchology*, 27(4):269-271.

Woolman, Lewis. 1897. Stratigraphy of the Fish House black clay and associated gravels, fossil horse, Unionidae and plant remains. *New Jersey Geological Survey, Report*, pp. 201-218.